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NSTL, Mississippi 39529

NORDA Report 90

January 1985

# A Towed Instrument Vehicle for Deep Ocean Sampling

Final Report

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Ocean Acoustics and Technology Directorate

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# Foreword

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Studies of horizontal variability in the ocean require the capability to sample on much shorter length scales than can be accomplished with a series of vertical stations. A towed instrument package is needed to make those horizontal measurements. Thus, there is a recurring need in oceanography for towed vehicles to carry instrumentation below the ocean surface. Usually these vehicles have been designed to perform a specific task. The vehicle described here is the result of an effort to produce a towed vehicle design that can accommodate a wider variety and a greater quantity of instrumentation than can earlier designs, and is also simple to construct and maintain. The vehicle design presented here requires only commonly available materials and simple machining. The simplicity of the design allows for easy modification to satisfy the special requirements of many potential users.



R. P. Onorati, Captain, USN  
Commanding Officer, NORDA

## **Executive summary**

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A vehicle that can take instrumentation into the ocean while being towed by a surface craft has been built. The vehicle body is a flooded, 8-foot-long cylinder stabilized at the tail and depressed by a short wing. Most of the structural loads are borne by four full-length radius plates. These plates divide the cylindrical body lengthwise into four wet compartments that have quadrant cross sections. Each quadrant can hold instrument payloads as large as  $5\frac{1}{2}$  inches in diameter. Each quadrant can be uncovered independently to service the payload. These features are improvements over previous designs for carrying an assortment of payloads. Construction cost was only \$3200. Design criteria, details of the construction, and results of an initial tow test of the towed body are presented.

# Acknowledgments

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The authors wish to acknowledge Mr. David C. Young who assembled the towed vehicle from the component parts and provided useful suggestions during design modification. We also thank Mr. Patrick J. Setser, Dr. Norman L. Guinasso, and Dr. David R. Schink of Texas A&M University for providing details of the design and towing characteristics of the Texas A&M winged fish. This project was funded by the Naval Ocean Research and Development Activity under Program Element 61153N, Herbert Eppert, Jr., program manager.

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# A towed instrument vehicle for deep ocean sampling

## Introduction

Oceanographers began by studying general ocean basin characteristics using a few water samples and have progressed to studying smaller scale features that require greater sampling densities. Observations of various parameters with depth began with determinations of salinity and temperature using water sample bottles and reversing thermometers, which could be hung on a wire and tripped at discrete depths. The advent of devices (CTDs) for continuously measuring depth distributions of temperature and conductivity led to an increased understanding of the smaller scale vertical features. Biologists and chemists were still faced with obtaining discrete water samples to make their measurements. Submersible pumps attached to CTD units, combined with fluorometers or transmissometers, have allowed the collection of almost continuous vertical profiles for some chemical and biological parameters (e.g., chlorophyll and micronutrients).

Detailed analysis of horizontal distributions in the surface ocean, however, has been notoriously difficult due to the high data densities required to determine a coherent picture of the ocean surface. Studies of horizontal variations have often been undertaken simply by spacing hydrocast or CTD stations closely along a transect line and contouring the data between the stations. In dynamic ocean areas, however, the variability of temperature and salinity, as well as chemical and biological parameters, occurs on horizontal length scales much shorter than can be studied with standard hydrocasting techniques. A new sampling strategy was needed to obtain the sample density required to study dynamic upper ocean processes. This strategy involves use of a towed instrumented vehicle that can be operated continuously in surface waters (down to 200 m) while the towing vessel is under way at speeds of up to 12 knots. Several such systems have been constructed in the past. A few have combined in situ instrumentation with a submersible pump in the tow vehicle to pump water to the deck of the ship for onboard chemical and biological analyses. A towed instrumented pumping system is highly desirable in providing the flexibility to meet analytical needs that cannot be achieved with electronic sensors alone.

This report describes the design and testing of the tow- ing vehicle developed by the Naval Ocean Research and Development Activity (NORDA) as part of a towed under- water pumping system (TUPS). This system will be used initially by NORDA scientists in a program to study the dynamic chemical and physical processes often observed in ocean frontal areas. The versatility of this tow vehicle will make it useful to many future research projects.

## Previous tow vehicles

Before design was begun on the tow vehicle described here, several existing tow vehicle designs were evaluated with respect to our system requirements. Our design criteria demanded that the tow fish be relatively lightweight, have a large internal volume for assorted instrumentation, and have the instruments easily accessible. Special consideration was given to the need to accom- modate a large-diameter tow cable required for pumping water from depth. Although many tow fish were considered, only three were evaluated in detail. Their design concepts and reason for their exclusion are presented in the following sections.

### Batfish

The "Batfish" programmable towed body (manufactured by Guildline Instruments, Smith Falls, Ontario, Canada) has been used quite successfully by oceanographers at Bedford Institute of Oceanography. Herman (1977) and Herman and Denman (1977) provided excellent examples of how it can be effectively used to study near-surface chlorophyll variations. Dessureault (1976) provided a de- tailed description of the system and its operation.

The Batfish is 4.4 ft long and 3.1 ft high, the wing span is 4.1 ft, and weight in air is 176 lb. The body is constructed of reinforced fiberglass, stainless steel, and aluminum. Payload capability is 50 lb. The Batfish ob- tains downward depression from a hydraulically actuated hydroplane that is controlled by a shipboard deck unit. The Batfish is towed with an electromechanical towing cable. The tow body can be programmed to "fly" a predetermined profile or to maintain a constant depth. Cost of the Batfish is approximately \$45,000.

A major advantage of the Batfish is the ability to program it to undulate along a sawtooth pattern in a vertical plane when towed from a moving ship. The sawtooth cycle length can be as short as 0.3 km in surface waters, which makes it suitable for studying oceanographic features on the scale from 1 to 10 km.

The Batfish was excluded because it had a small payload capability and had never been configured with the large-diameter (one-inch) cable needed for a pumping system. While the ability to undulate the tow body is highly desirable, the loss of payload capability was overriding. We also desired a tow vehicle design that had been proven to work with a deep-towed pumping system. The Batfish met neither of these requirements.

## Fathom Oceanology oceanographic towed fish

The oceanographic towed fish (manufactured by Fathom Oceanology Limited, Port Credit, Ontario, Canada) is a streamlined, multipurpose tow vehicle. This towed fish has been used successfully in towed pumping systems by Texaco Oil Company and later by Texas A&M University (Wiesenburg and Schink, 1978).

The Fathom towed fish is 5.0 ft long, has a 1.5 ft diameter and a weight in air (50% ballast) of 980 lb. Lead plates are used for ballast. The frame is constructed of high-strength aluminum and is covered with high-impact ABS plastic or polycarbonate shells. The Fathom fish has rear fins and stabilizers and adjustable trim tabs. Payload volume is 5.2 ft<sup>3</sup>.

The Fathom towed fish achieves downward depression from lead ballast weights bolted into the upper half of the fish. The fish, without instruments, weighs 84 lb. With the maximum 50% lead ballast, a maximum weight of 1000 lb is attained. Since the Fathom towed fish has no dynamic control, the depth of the towed fish is determined by the length of cable deployed. Cost of the Fathom towed fish is approximately \$12,000 (1980 price).

Three factors led to the exclusion of the Fathom fish for our purposes. The 1000-lb weight (without instruments) is too heavy to launch and retrieve safely at sea without a specially designed launching cradle. Our launching requirements excluded such a device. Also, the instrument payload volume was too small. Finally, the instruments on the Fathom fish are mounted in the bottom half of the fish. This configuration makes instrument access difficult without the Fathom launching cradle.

## Texas A&M winged fish

An underwater tow vehicle was designed and constructed at Texas A&M University with funding from

the Office of Naval Research (Contracts N00014-75-C-0537 and N00014-80-C-0113). Their fish was used in a deep-towed pumping system to explore changes in chemical and biological properties in near-surface waters.

The Texas A&M fish is 3.9 ft long and 2.1 ft high; weight in air is 110 lb. The fish body is cylindrical (diameter of 1.0 ft) and is constructed from an aluminum pipe with internal ribs to support the tow point and a removable upper section for instrument installation. The Texas A&M fish achieves downward depression from a wing (dimensions—1.0 ft x 3.4 ft) angled at 8° to the body, which gives the fish an effective weight of 500 lb at a speed of 10 knots. The winged fish was designed with critical advice from Reece Folb and Richard Knutson of the Towed System Branch, David W. Taylor Naval Ship Research and Development Center. Setser et al. (1983) briefly describe the Texas A&M winged fish and provide examples of its utility in studying nutrient and chlorophyll variations in the Atlantic Ocean off the U.S. east coast.

For our purposes, the winged fish designed by Texas A&M University had several advantages over both the Batfish and the Fathom Oceanology tow vehicle. The dynamic depression allowed the winged fish to be much lighter and easier to handle than the Fathom tow vehicle. The payload volume of the Texas A&M fish was also larger than that of the Batfish, although it was still too small for our needs.

A major drawback to the Texas A&M fish is the difficulty in accessing the installed instrumentation. The skin of the fish (walls of the aluminum pipe) is used to provide the structural integrity of the vehicle. The instruments are also attached to the fish skin with mounting brackets. To access the lower instruments, upper instruments must be removed. Our design criteria dictated access to any instrument without having to disturb others. For this reason, as well as the small size, the Texas A&M fish design could not be used exactly. The tow vehicle that we designed employs many design concepts used in the Texas A&M fish, but incorporates several unique features that make it more flexible to use and simpler to fabricate and maintain.

## TUPS fish design considerations

The TUPS vehicle design was affected by many conflicting requirements. The vehicle must be capable of tow speeds to 12 knots and depths to 200 m. The vehicle envelope should be similar to that of proven towed bodies (see previous section) and be easy to fabricate and maintain, but capable of carrying up to 20 linear feet of payload

as large as  $5\frac{1}{2}$  inches in diameter. It is undesirable to have to move any item of payload to gain access to another. Included in the payload are an electric motor and pump, which must have a seawater inlet near the nose and various optical sensors with special field-of-view requirements. Provision for reasonable seawater flow past other sensors in the body is also required.

The outside diameter of the fuselage is 14.25 inches with an overall length of 8 ft, 3 inches. The wingspan is 4 ft with a 16-inch chord. The rationale for the parts configuration of the vehicle will be explained in nose-to-tail order. Drawings that describe the vehicle envelope, assemblies, and details of the parts are appended. Pictures of the assembled tow vehicle are shown in Figures 1, 2, and 3.

The nose (Drawing #84-333-01-102) is made of lead in anticipation of the body being tail heavy. Although the weight and balance information for the vehicle and payload were unknown when fabrication started, we knew that the tow point would be approximately one-third of the vehicle length behind the nose, and that the tow point and the centers of buoyancy and gravity should be nearly on the same vertical line. Making the nose of lead with a weight of 80 lb will, therefore, almost surely decrease the problem of adding balance weights forward for proper trim when the vehicle is being readied for deployment. Also the pump and motor, relatively heavy payload items, will be positioned in the lower quadrant forward to help move the center of gravity forward and down. In addition, the longitudinal position of the tow point can be adjusted to aid in balancing the vehicle. The final adjust-

ment will be made by adding weights and perhaps syntactic flotation. The center hole in the nose is large enough to allow forward penetration by the pump inlet and permits flow of seawater through the vehicle.

The nose plate (Drawing #84-333-01-101) provides anchorage for the nose attachment bolts and temporary alignment support for the nose by means of a shoulder on its periphery. The end brackets (Drawing #84-333-01-101) join the nose plate to the four radius plates (Drawing #84-333-01-201) which, together with the interior and exterior angles, are the spine of the vehicle. The radius plates are symmetrical such that either end can be placed forward. The larger holes in the plates provide for communication between the longitudinal quadrants. The interior angles (Drawing #84-333-01-202) permit joining of the inner edges of the radius plates near the center line of the vehicle. They are identical but not symmetrical in the manner of the radius plates. Their orientation by pairs on the radius plates prevents interference of their mounting bolts. The exterior angles (Drawing #84-333-01-202) permit joining of the outer edges of the radius plates with the skin panels. The exterior angles are through-bolted to the radius plates but contain threaded inserts to receive the screws that fasten the skin panels. The skin panels (Drawing #84-333-01-203) are intended to be the only parts that are normally removed for service to the payload. They are fastened with hex-head screws instead of flat-head screws so that precise location of the mounting holes is not necessary. The upper quadrant is necessarily covered by two pieces of skin because of the wing mounts, but each of the other quadrants is covered with a single panel

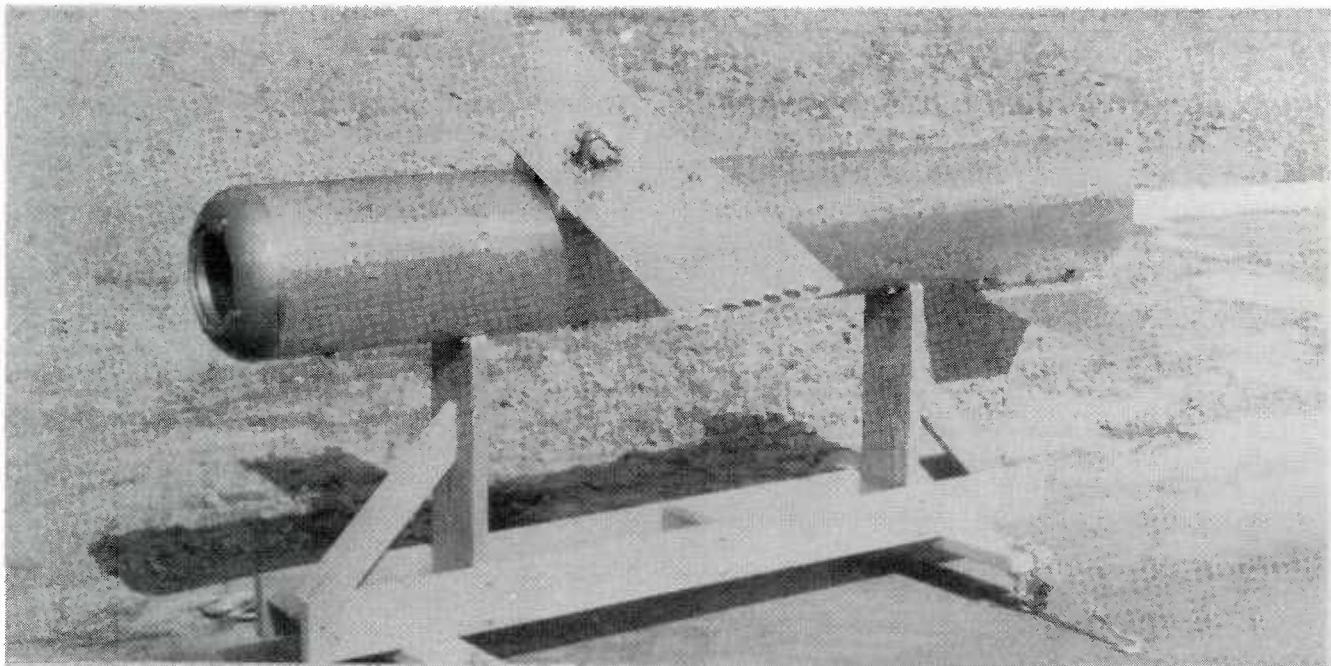


Figure 1. Photograph of the assembled towed vehicle, supported on a wooden stand.

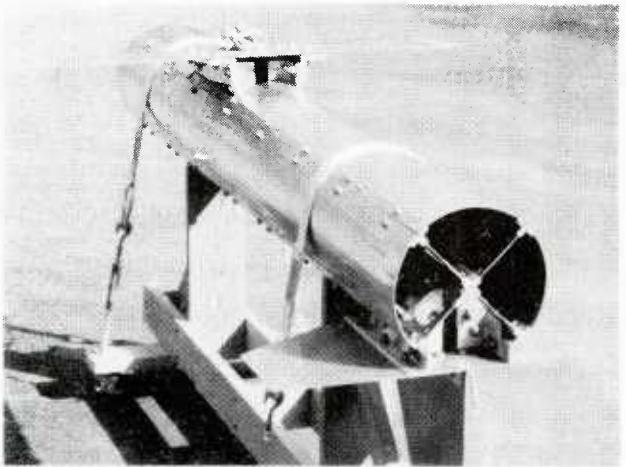


Figure 2. Rear view of the towed vehicle showing the quadrant cross sections formed by the radius plates.

that should not be further divided. These panels are structural members that resist longitudinal bending of the vehicle, especially near the tow point.

The wing (Drawing #84-333-01-301) is made of 1/4-inch plate and is mounted with a negative angle of attack of  $8^\circ$ . The leading and trailing edges are beveled on the under-

side to provide an approximately foil-shaped cross section to enhance the downward force produced. The wing tips are perforated to reduce the tip vortices, as well as to provide attachment points for taglines. The wing is attached by three bolts to each of its mounts (Drawing #84-333-01-302). The three sets of holes in the wing and three sets of holes in the mount provide for nine different positions of the wing on the body. The tow point is also attached to the wing, ideally at the same longitudinal position as the center of (downward) lift. This configuration avoids the problem of transmitting the wing forces through the body and makes trimming the vehicle easier, but there must be enough service loop in the cable and hose under the tow point to accommodate the various wing positions. The wing mounts are attached to hangers (Drawing #84-333-01-303), which are, in turn, attached to anchors (Drawing #84-333-01-303) bolted to the radius plates. The hanger and anchors on the left side are mirror images of their counterparts on the right side. If they are each rotated  $180^\circ$  about their vertical axes and moved to the opposite side of the body, new positions for the wing mounts are created. This effectively doubles the number of possible positions of the wing to 18. The anchors in the lower three quadrants are used to distribute the gravitational and inertial forces on the vehicle to all four radius

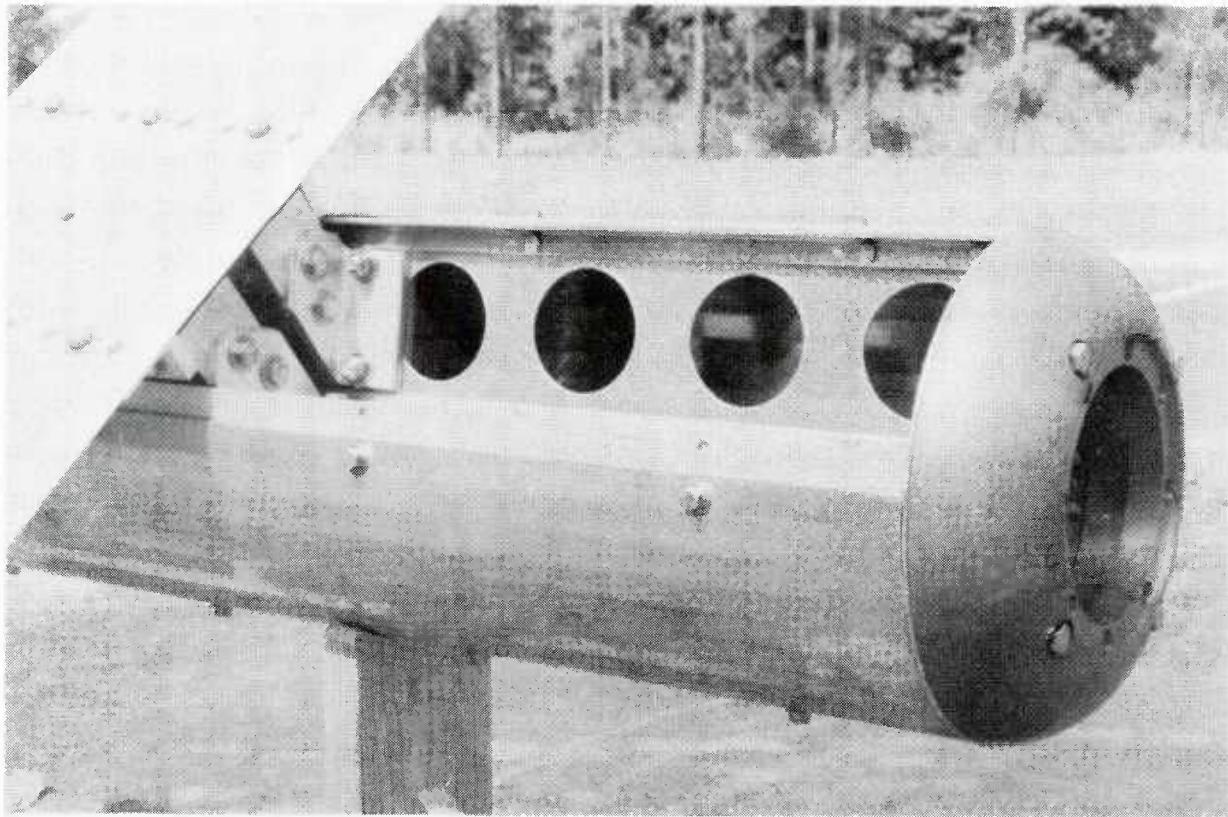


Figure 3. Photograph of the nose and forward section with a skin panel removed to reveal the large holes in the radius plates, which allow communication between the longitudinal quadrants.

plates. To achieve this, and to maintain the  $90^\circ$  angle between the radius plates, they must be connected by anchor ties (Drawing #84-333-01-302). The skin panels are curved into a pre-buckled configuration and cannot serve as rigid connectors to resist circumferential forces.

The horizontal stabilizer (Drawing #84-333-01-402) is mounted in essentially the same manner as the wing except that the anchors (Drawing #84-333-01-303), hangers (Drawing #84-333-01-303), and mounts (Drawing #84-333-01-404) are made of lighter angles and the angle of attack is zero. The vertical fin (Drawing #84-333-01-401) is joined to the stabilizer by two angles (Drawing #84-333-01-403). The longitudinal position of the vertical fin is adjustable. It is mounted below the fuselage to help orient the vehicle during launch.

Fabricating the TUPS fish from the detailed drawings was done in two parts. The fuselage (radius plates and skin panels) was manufactured and assembled by Jurisch Engineering, Slidell, Louisiana. The nose, wing, and tail subassemblies were fabricated by Cuevas Machine Shop, Perkinston, Mississippi. The tow vehicle was assembled by Mr. David C. Young of NORDA.

## Tow test

The first tow test of the TUPS vehicle was conducted at the U.S. Geological Survey Test Tank at NSTL, Mississippi, in October 1984. The tank dimensions are 12 ft x 12 ft x 450 ft. The vehicle contained no internal attitude instrumentation or payload, but the tow line angle and tension were measured. The tow forces were transmitted through a 3-inch-diameter ball centered 5-1/3 inches behind the leading edge of the wing. The tow test configuration is shown schematically in Figure 4.

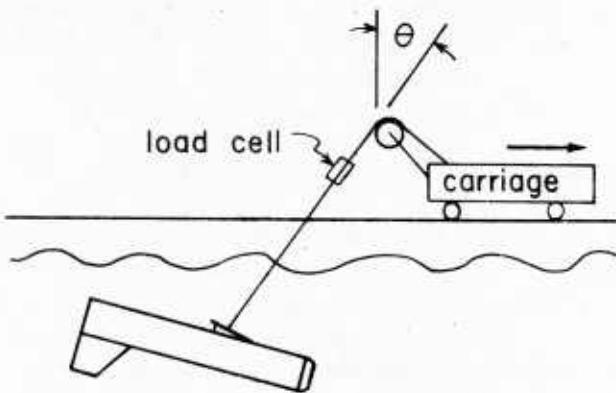


Figure 4. Schematic diagram of the tow test experimental configuration.

The purposes of the tow test were to determine if vehicle stability difficulties would be likely and to bracket the speed and force characteristics of the vehicle. The test results are shown in Table 1. The vehicle appeared to be extremely stable. Further tow tests were postponed until after the installation of payload.

## Conclusions

The cylindrical, four-compartment, winged tow vehicle described here meets our needs for a towed research vehicle significantly better than previous designs. The vehicle is extremely stable. Each of the four separate compartments is capable of holding a 5 1/2-inch-diameter cylindrical payload. Each quadrant is individually accessible, and the flat radius plates make instrument attachment

Table 1. Tow test results with empty vehicle.

Run Number <sup>a,b</sup>	Speed (knots)	Tow Cable Angle, $\theta$ (degrees)	Load Cell Tension <sup>c</sup> (pounds)	Vertical Component of Load Cell Tension <sup>d</sup> (pounds)	Vertical Component of Hydrodynamic Forces (pounds)	Drag Force (pounds)
1	3	7	320	320	80	40
2	6	18	550	520	280	170
3	9	26	910	810	570	410
4	3	7	300	300	60	40
5	6	17	520	500	260	150
6	9	26	880	790	550	390

<sup>a</sup>Run numbers 1-3, vehicle attitude in water at zero velocity,  $10.9^\circ$  nose down. Leading edge of wing 64 cm aft of skin-nose plate interface.

<sup>b</sup>Run numbers 4-6, vehicle attitude in water at zero velocity,  $2.8^\circ$  nose up. Leading edge of wing 59 cm aft of skin-nose plate interface.

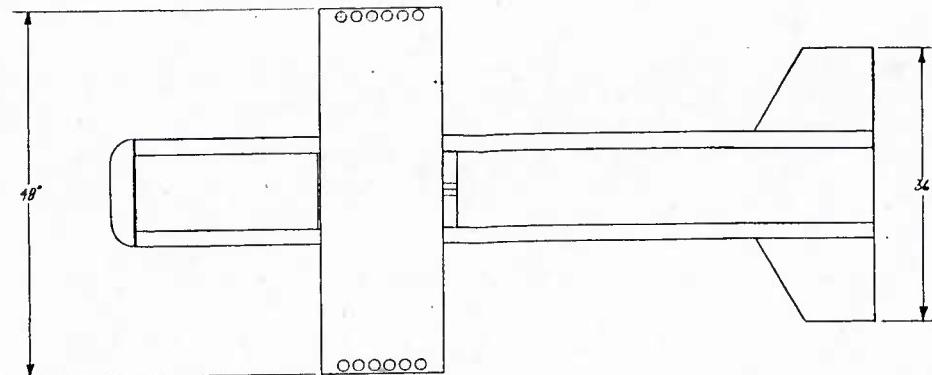
<sup>c</sup>Force measurement error +10 lb, -0 lb.

<sup>d</sup>Vehicle weight in water is 240 lbs.

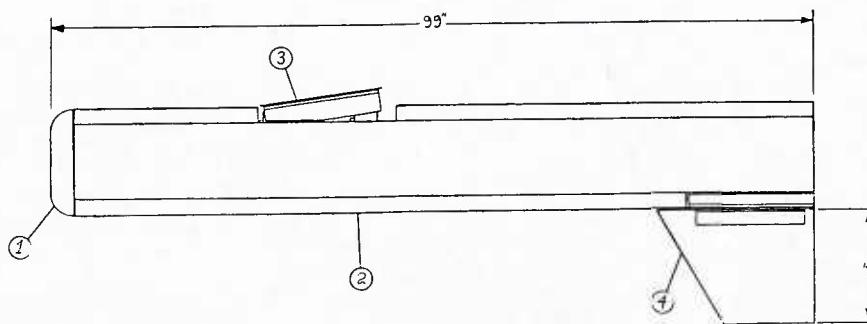
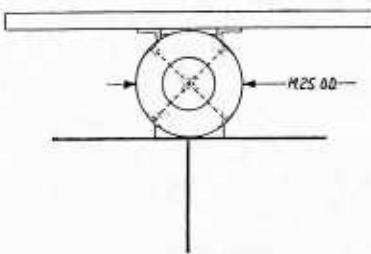
simple. The angled wing gives sufficient downward depression (550 lb at 9 knots) to tow at considerable depth without having to heavily ballast the vehicle. Fabrication cost of the NORDA TUPS fish (\$3200, 1984 price) is significantly less than either of the commercially available tow vehicles that were evaluated.

## References

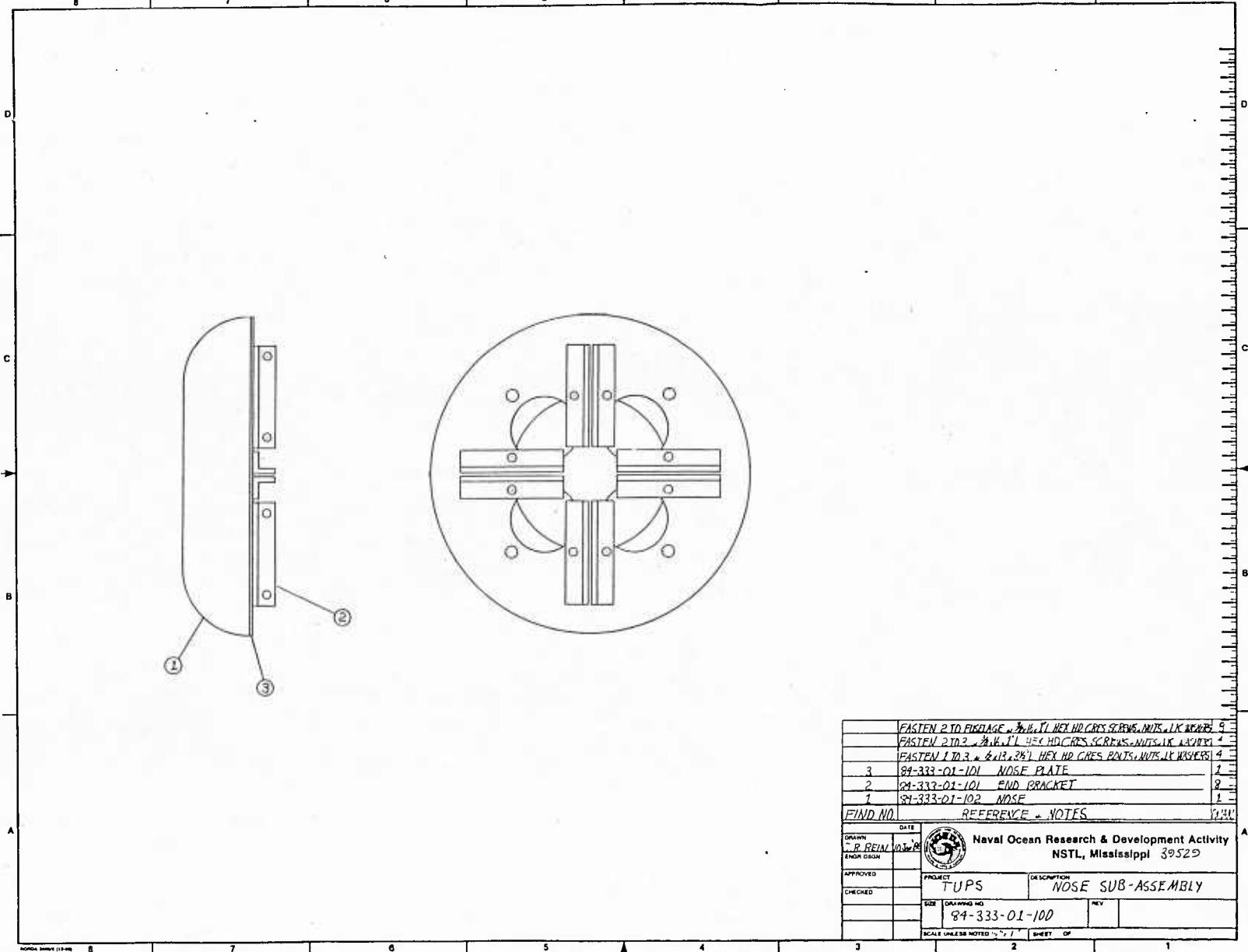
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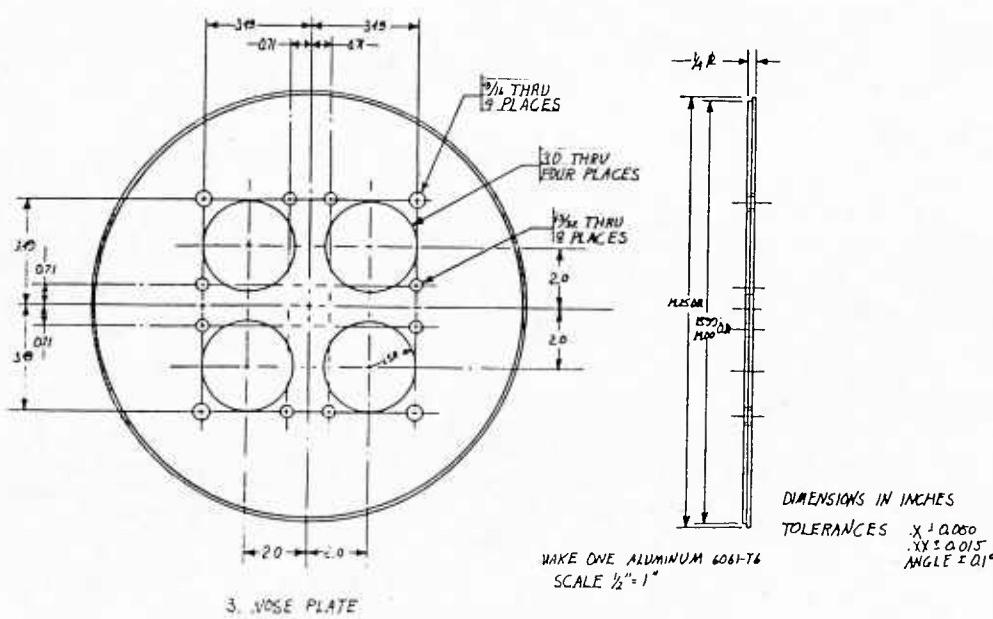
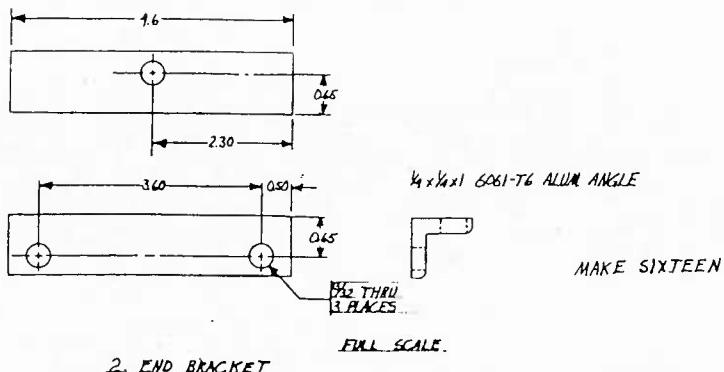


NOTE  
 INTERIOR DIVIDED INTO 7" RADIUS  
 QUADRANTS. QUARTER CIRCLE  
 SKIN PANELS CAN BE REMOVED  
 INDIVIDUALLY.  
 HIGHEST POINT OF WING  
 IS ADJUSTABLE.  
 WING AND STABILIZER ROOTS  
 PARTIALLY OBSTRUCT ADJACENT  
 QUADRANTS.

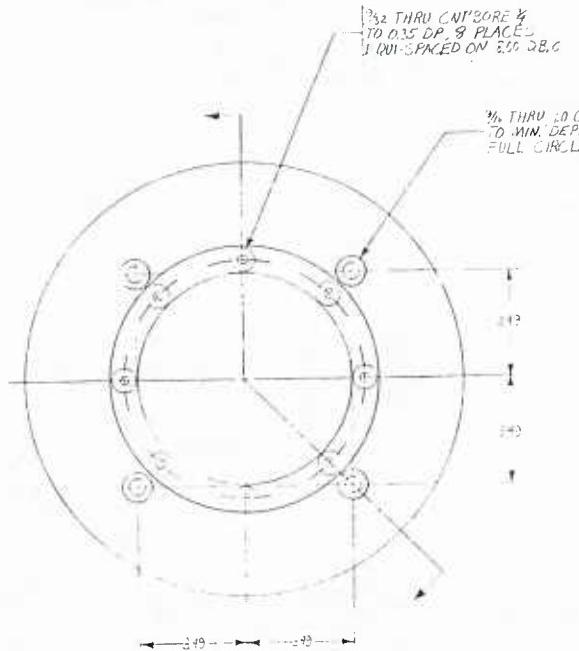


4	24-322-01-900 TAIL SUR-ASSEMBLY
3	24-322-01-300 WING SUR-ASSEMBLY
2	24-322-01-200 FUSELAGE SUB-ASSEMBLY
1	24-322-01-100 NOSE SUR-ASSEMBLY
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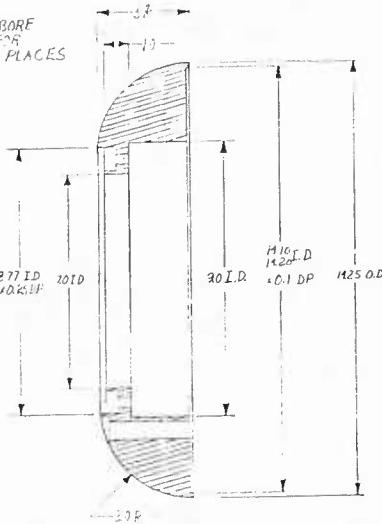




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2 NOSE

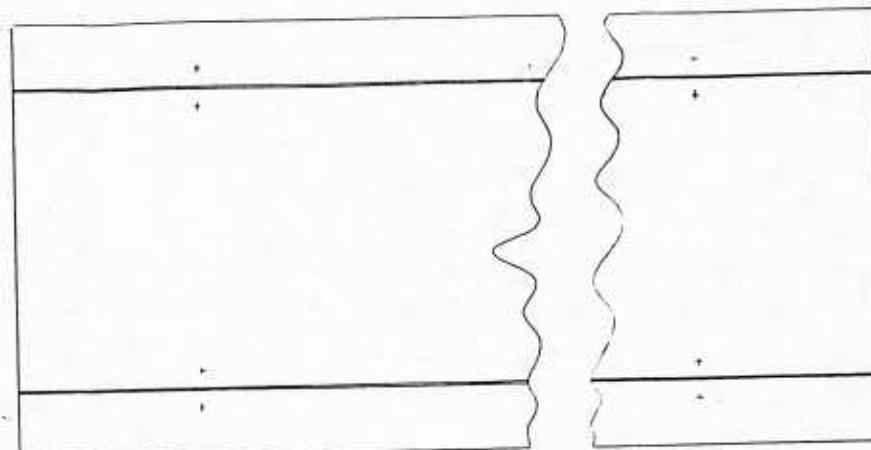
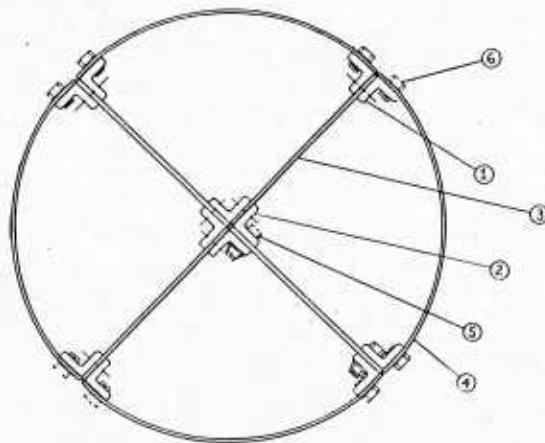


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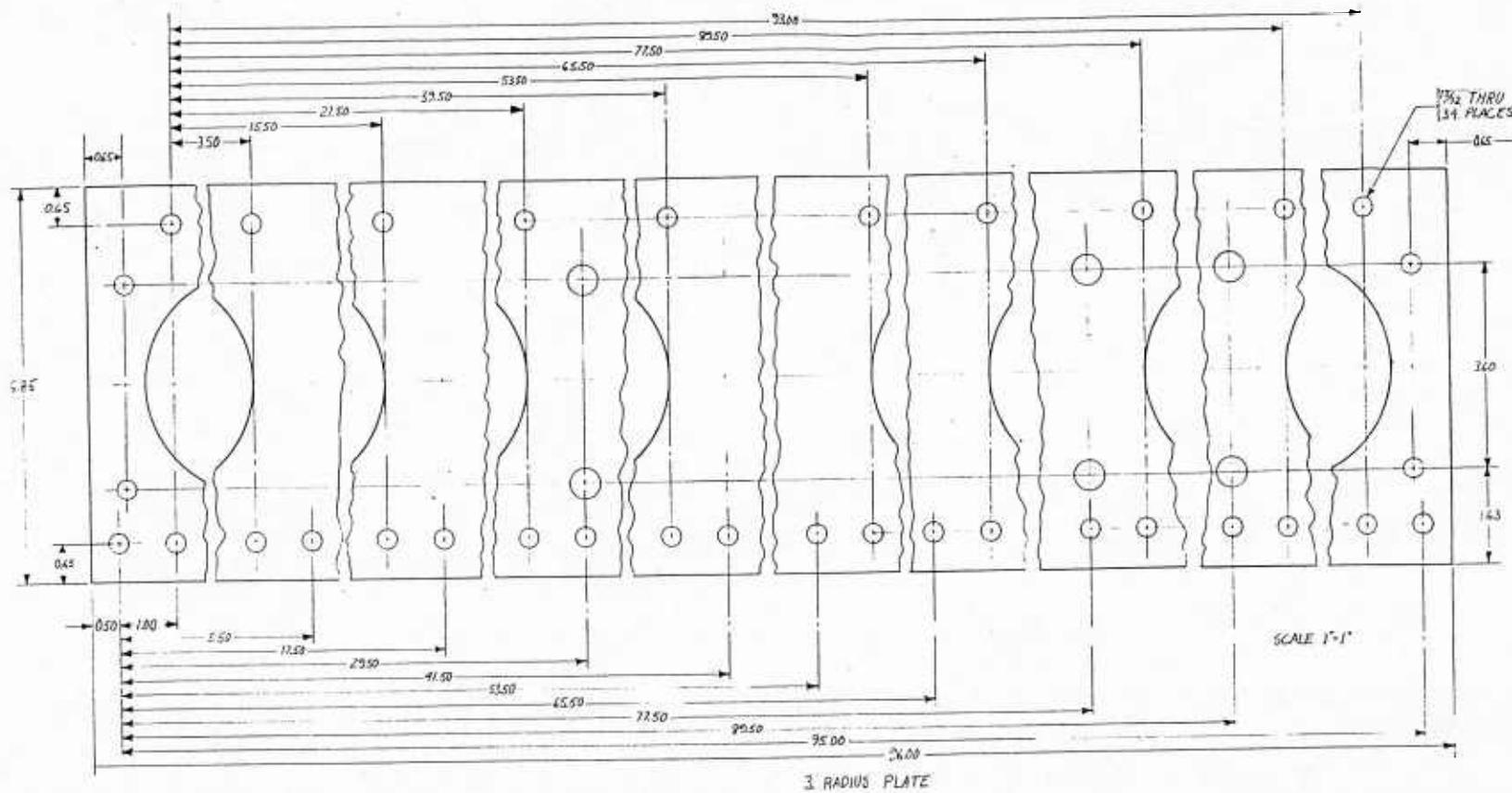
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ANGLE ± 1°

MADE ONE MATERIAL, LEAD  
SCALE 1/8 = 1"

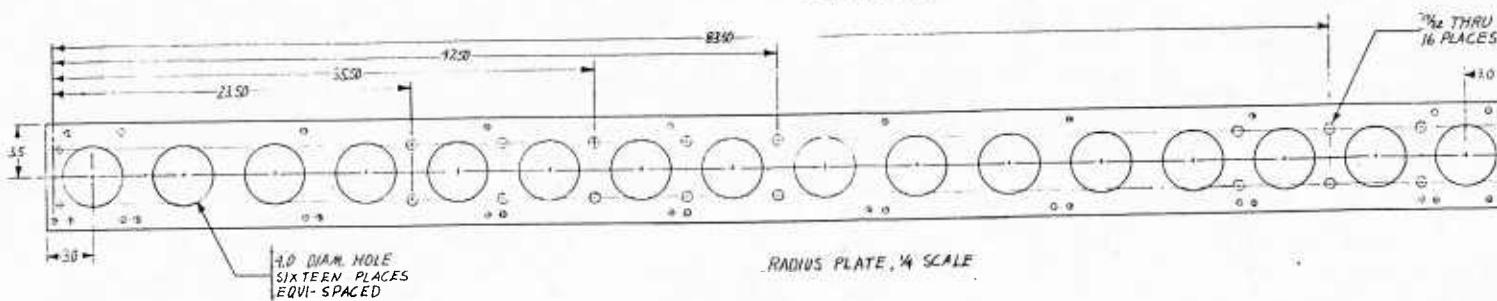
C.B. REIN 6/18/21	NAVAL AIRCRAFT RESEARCH, DEVELOPMENT ACTIVITY NSTL MISSISSIPPI 33223	
	TUPS	NOSE
	34-333-01-102	



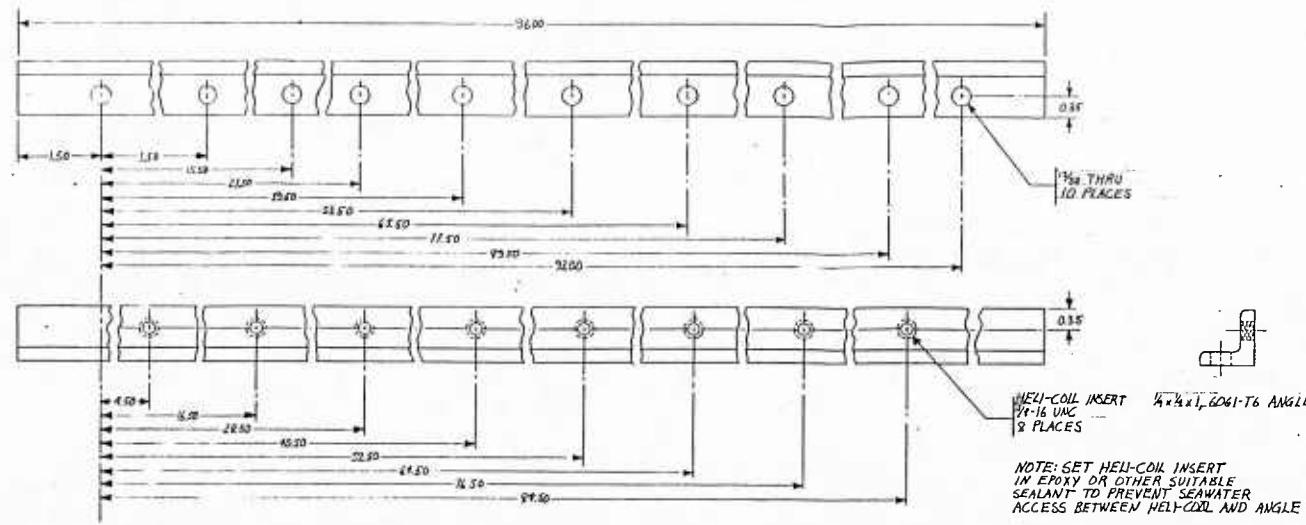
ITEM		DESCRIPTION	REFS	QUANTITY
6	3/8x16 1/4 SCREW	3/8" SELF LOCKING SCREW, HEX HEAD	64	
5	3/8x16 1/4 SCREW	" NUT HEX HEAD SCREW	80	
4	SKIN	ALUM 24-78	24-333-01-203	1
3	RADIUS PLATE	24-78	24-333-01-201	1
2	INTERIOR ANGLE	24-78	24-333-01-202	1
1	EXTERIOR ANGLE	24-78	24-333-01-202	1
MATERIAL SPEC		PREFERENCE	NOTES	WMA
CREFIN 24333		NAVAL OCEAN RESEARCH & DEVELOPMENT ACTIVITY NGT, MISSISSIPPI 39529		
-15		FUSELAGE SUB-ASSEMBLY		
34-333-01-200			1/2"=1"	



DIMENSIONS IN INCHES  
TOLERANCES DX  $\pm 0.050$   
 $DX \pm 0.015$   
FRAC =  $\frac{1}{16}$   
MATERIAL: ALUM. 6061-T6

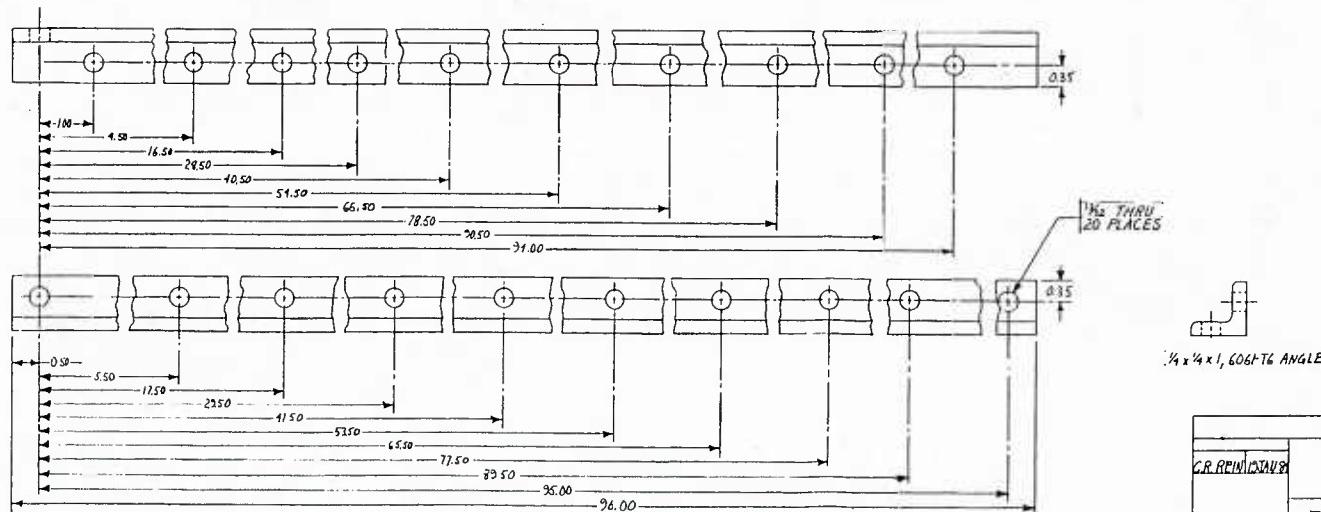


C.R.REIN 2010/01	NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY NSTL, MISSISSIPPI 39529
TUPS	RADIUS PLATE
	84-333-01-201



1 EXTERIOR ANGLE

NOTE: SET HELI-COIL INSERT  
IN EPOXY OR OTHER SUITABLE  
SEALANT TO PREVENT SEAWATER  
ACCESS BETWEEN HELI-COIL AND ANGLE

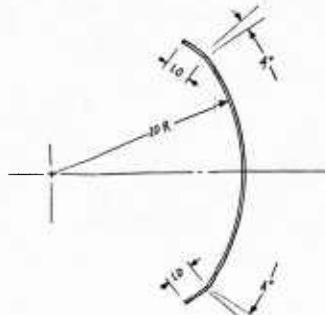


2. INTERIOR ANGLE

DIMENSIONS IN INCHES  
TOLERANCES OX,  $\pm 0.050$   
OX,  $\pm 0.015$   
FRAC  $\pm \frac{1}{64}$

CR REINFORCER	NAVAL OCEAN RESEARCH - DEVELOPMENT ACTIVITY NSTL, MISSISSIPPI 39529	
	TUPS	INTERIOR ANGLE, EXTERIOR ANGLE
	84-333-01-202	-12

DIMENSIONS IN INCHES  
TOLERANCES  $\Delta X \pm 0.050$   
 $\Delta Y \pm 0.015$   
FRAC.  $\pm \frac{1}{16}$   
ANGLE  $\pm 0.1^\circ$

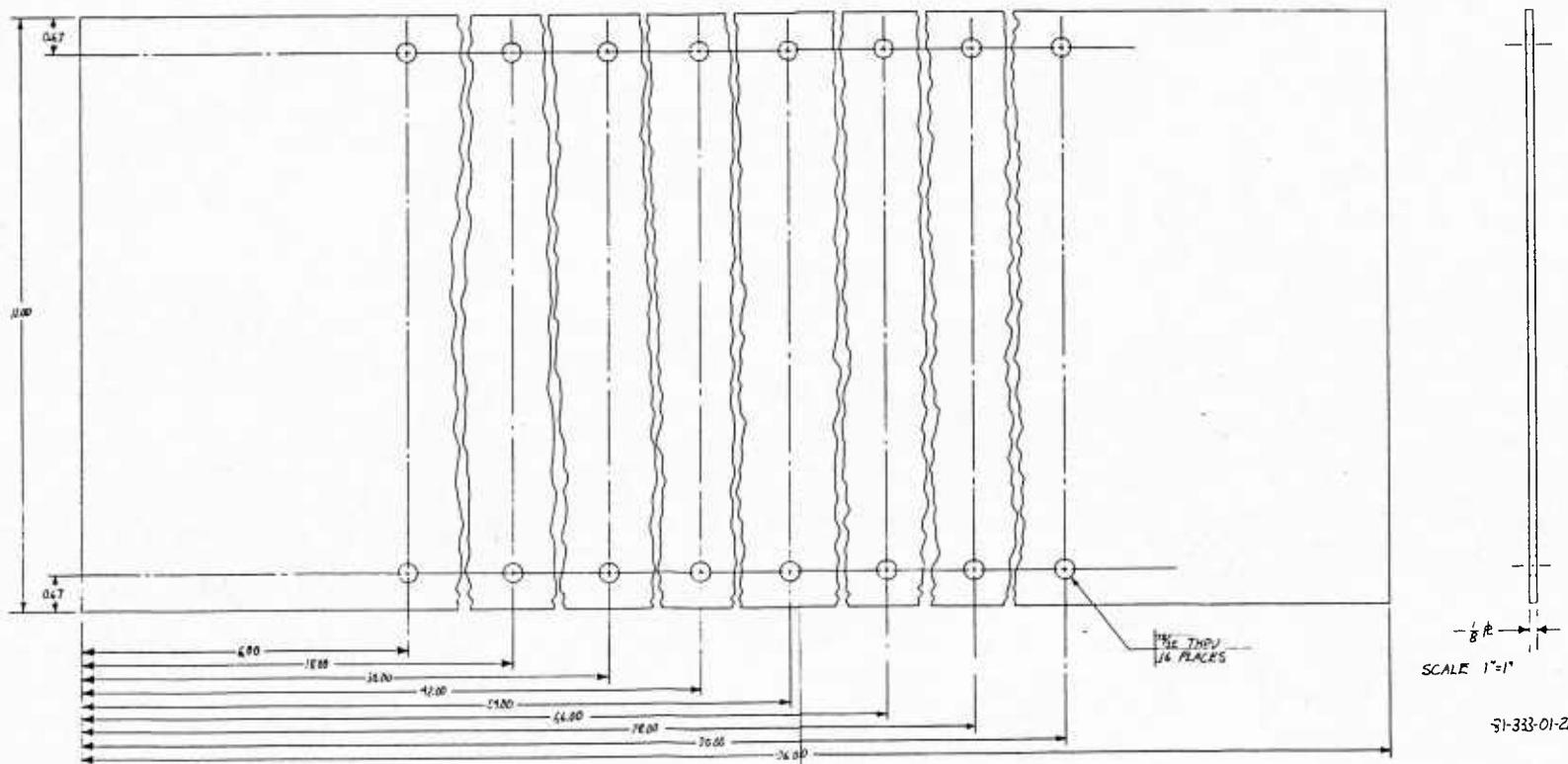


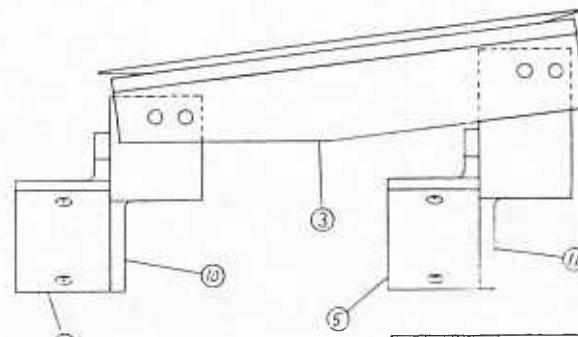
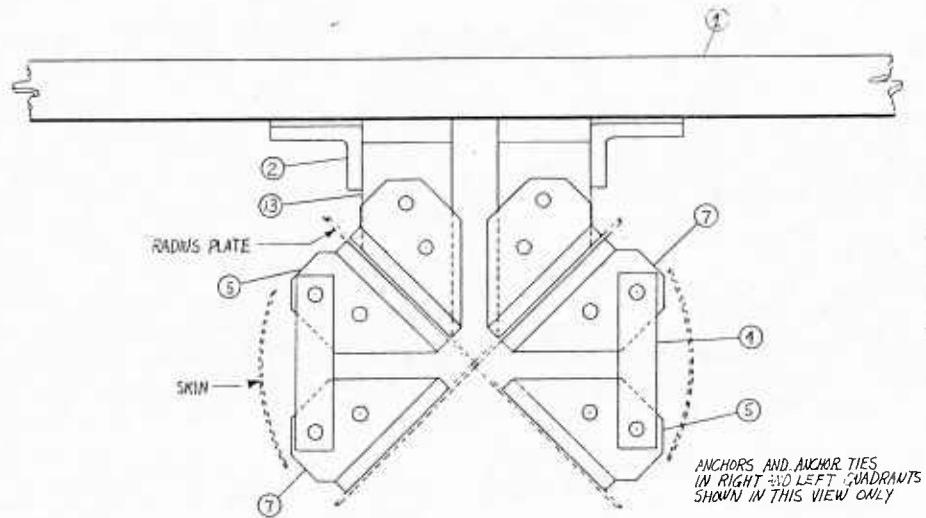
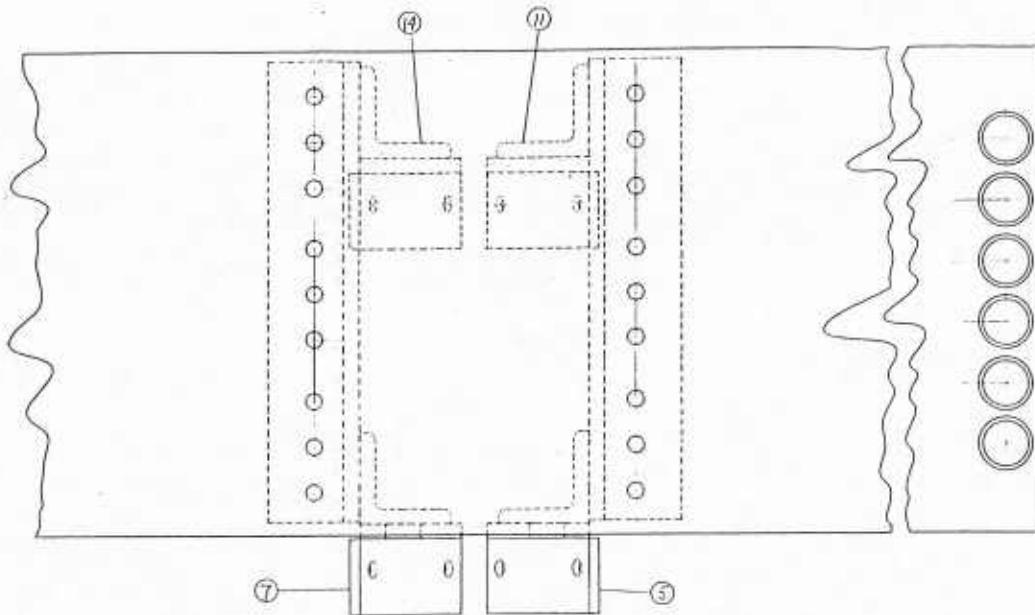
MANUFACTURE SKIN QUADRANT  
BLANK AS SHOWN BELOW THEN BREAK OR  
ROLL TO 20 ID AND BREAK 1"  
ALONG LONG EDGES AS SHOWN.

LONG EDGES SHOULD LIE FLAT ON  
EXTERIOR ANGLES WHEN ASSEMBLED

1. SKIN QUADRANT...  $\frac{1}{2}$  SCALE

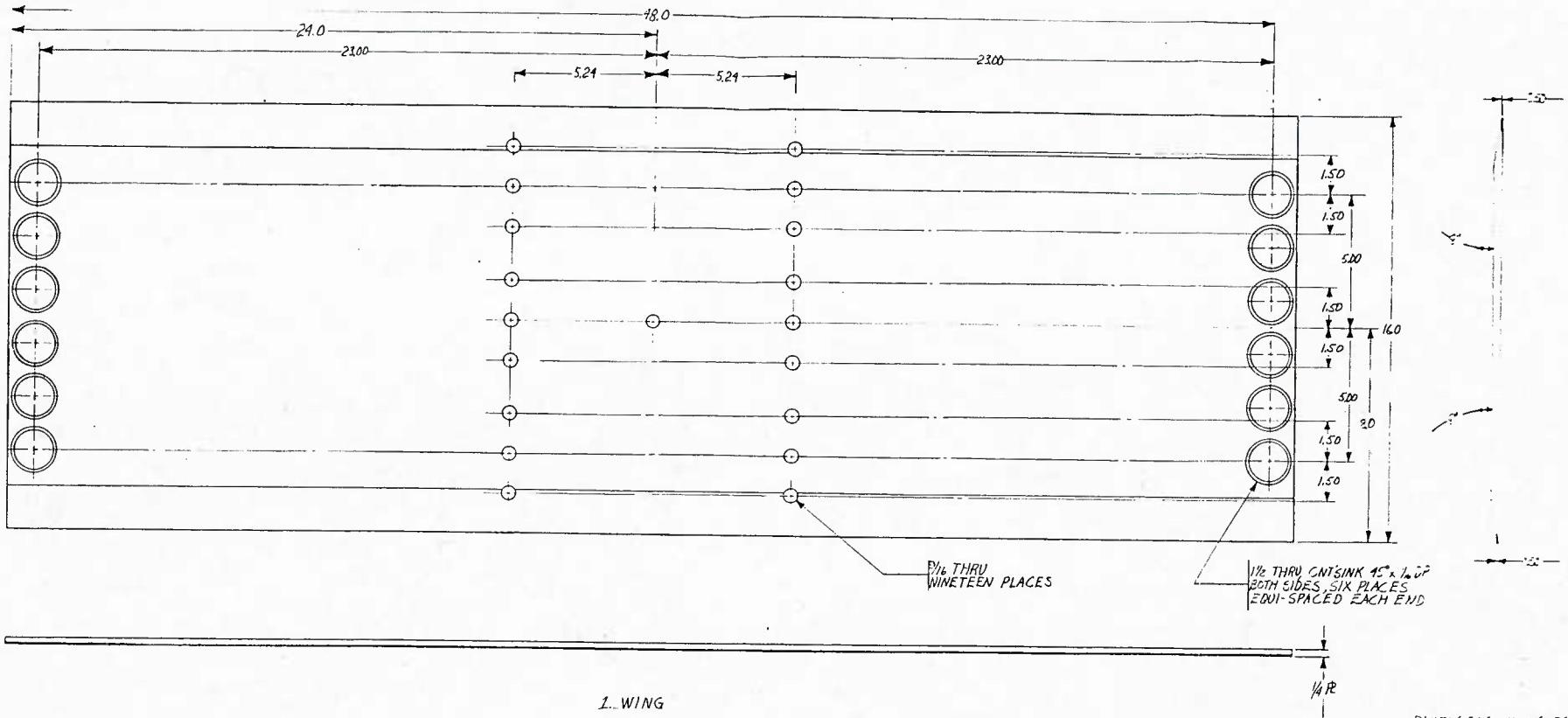
C.R.REIN JAW	NAVAL OCEAN RESEARCH + DEVELOPMENT ACTIVITY	
	NSTL, MISSISSIPPI 39529	
	TUPs	SKIN
84-333-01-203		





17	FASTENERS TO RADIUS PLATE TO 7 . K-B.1/4" L HEX HD CRES BOLTS, NUTS, LK WASHERS	3
15	FASTENERS TO RADIUS PLATES . K-B.1/4" L HEX HD CRES BOLTS, NUTS, LK WASHERS	2
16	FASTENERS TO 8-7 . K-B.1/4" L HEX HD CRES BOLTS, NUTS, LK WASHERS	2
16	FASTENERS TO 5-4 . K-B.1/4" L HEX HD CRES BOLTS, NUTS, LK WASHERS	2
16	FASTENERS TO 3-2 . K-B.1/4" L HEX HD CRES BOLTS, NUTS, LK WASHERS	4
16	FASTENERS TO 2-1 . K-B.1/4" L HEX HD CRES BOLTS, NUTS, LK WASHERS	4
15	FASTENERS TO 2-3 . K-B.1/4" L HEX HD CRES BOLTS, NUTS, LK WASHERS	6
19	84-333-01-303 RIGHT AFT WING HANGER	1
13	84-333-01-303 RIGHT FORWARD WING HANGER	1
11	84-333-01-303 LEFT AFT WING HANGER	1
10	84-333-01-303 LEFT FORWARD WING HANGER	1
7	84-333-01-303 RIGHT WING ANCHOR	0
5	84-333-01-303 LEFT WING ANCHOR	6
4	84-333-01-302 ANCHOR TIE	4
3	84-333-01-302 LEFT WING MOUNT	1
2	84-333-01-302 RIGHT WING MOUNT	1
1	84-333-01-301 WING	1
WING REFERENCE + NOTES		
244		

C.R. REIN	NAVAL OCEAN RESEARCH + DEVELOPMENT ACT, 7 NSTL, MISSISSIPPI 39529	
TUPS	NING SUB-ASSEMBLY	
84-333-01-300		
A = 1"		



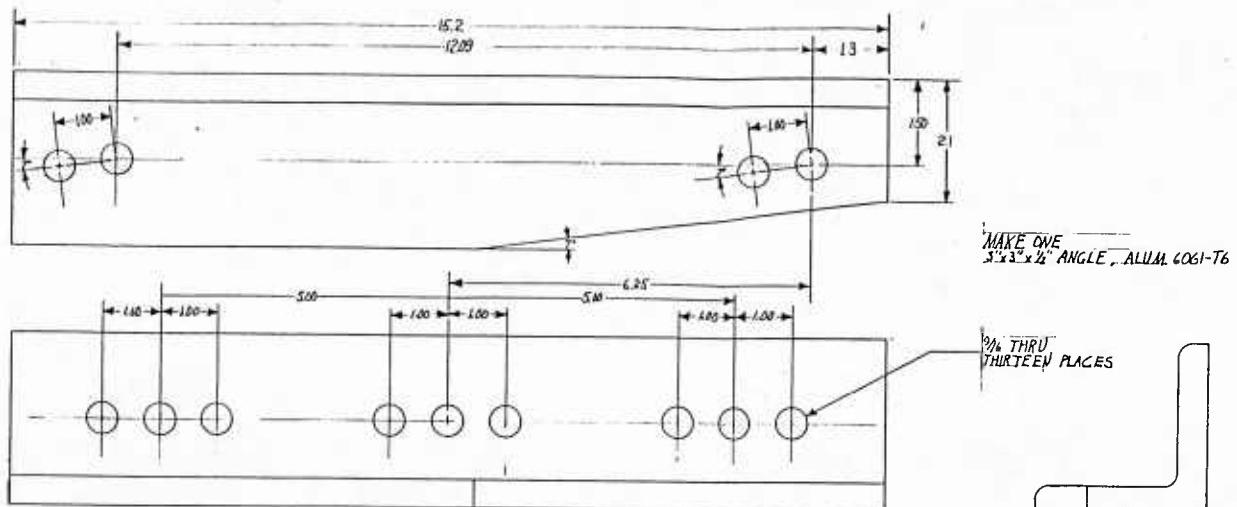
1. WING

MAKE ONE  
ALUM 6061-T6

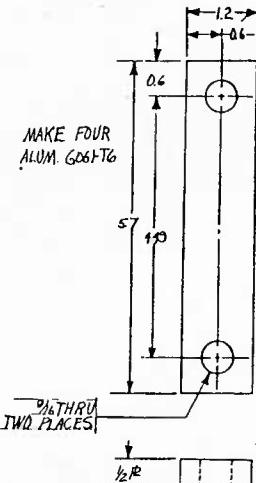
DIMENSIONS IN INCHES

TOLERANCES  
D.E.S.C.  
S.W.E.S.E  
FLAT ± 6°  
ANGLE ± 4°

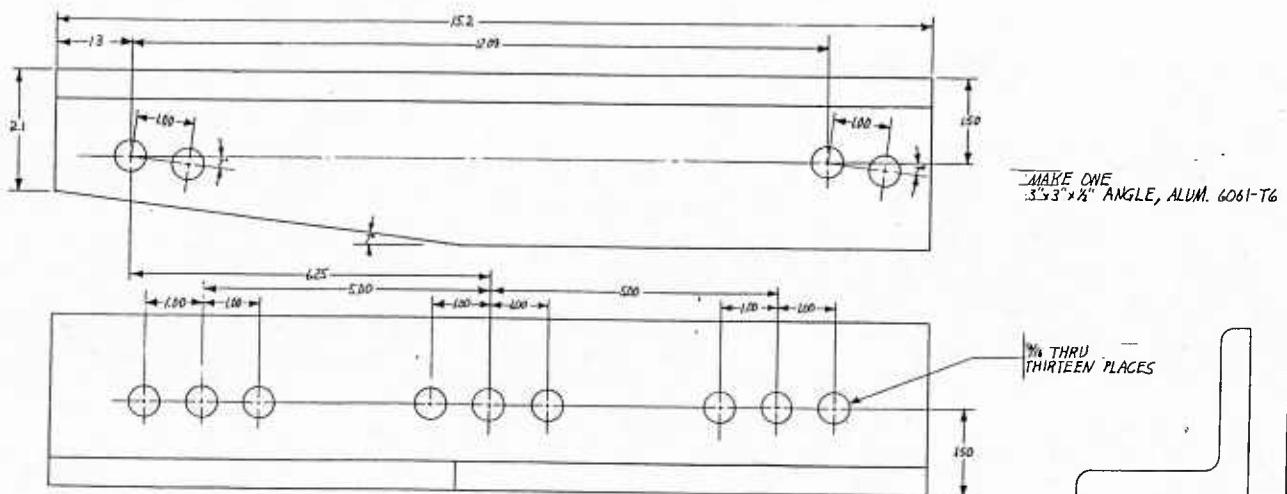
G.R.REIN	NAVAL OCEAN RESEARCH + DEVELOPMENT ACTIVITY	
	NSTL, MISSISSIPPI 39529	
TUPS	.WING	
84-333-01-301		1/2"-1"



2. RIGHT WING MOUNT



4. ANCHOR TIE

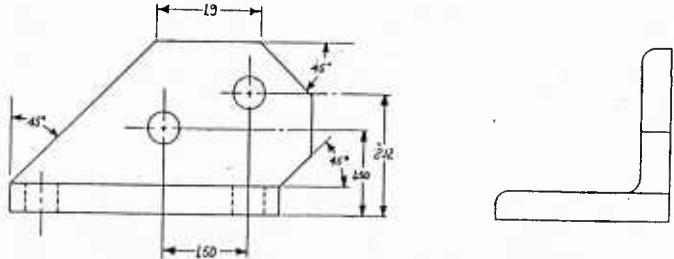
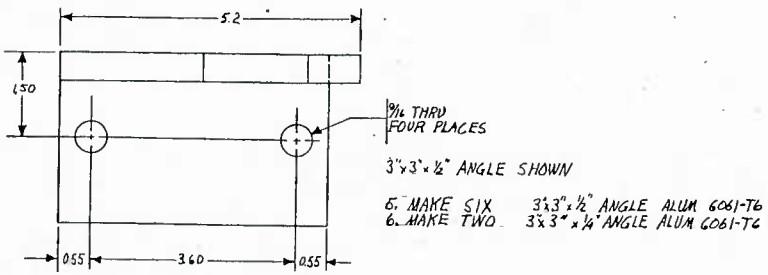


3. LEFT WING MOUNT

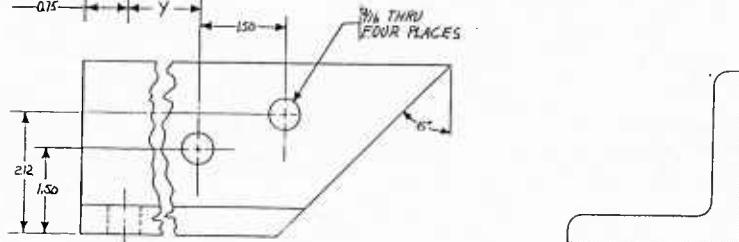
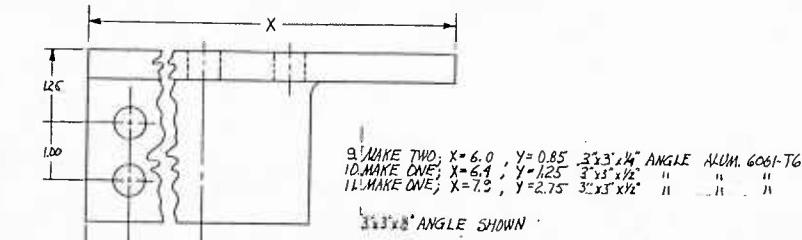
DIMENSIONS IN INCHES  
TOLERANCES:  $\Delta X, \Delta Y \pm 0.050$   
 $\Delta XY, \Delta Z \pm 0.015$   
FRACT.  $\pm 1/64$   
ANGLE  $\pm 1^\circ$

SAW CUT OK  
NO FLAME OR ARC CUTTING

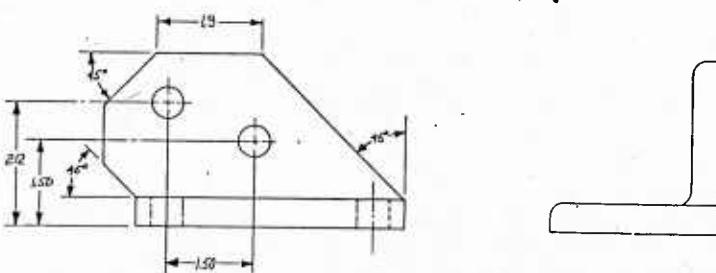
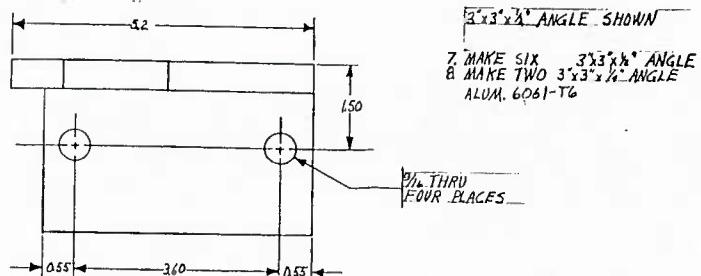
C.R.REIN	
NAVAL OCEAN RESEARCH & DEVELOPMENT ACTIVITY NSTL, MISSISSIPPI 39529	
TUPS	WING MOUNTS & ANCHOR TIE
	89-333-01-302
$1'' = 1'$	



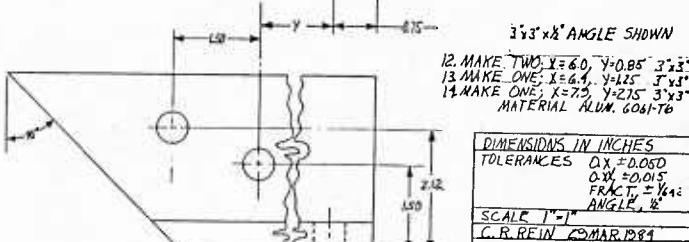
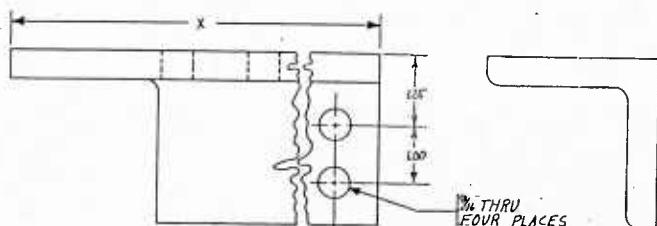
5. LEFT WING ANCHOR  
6. RIGHT TAIL ANCHOR



9. RIGHT TAIL HANGER  
10. LEFT FORWARD WING HANGER  
11. LEFT AFT WING HANGER

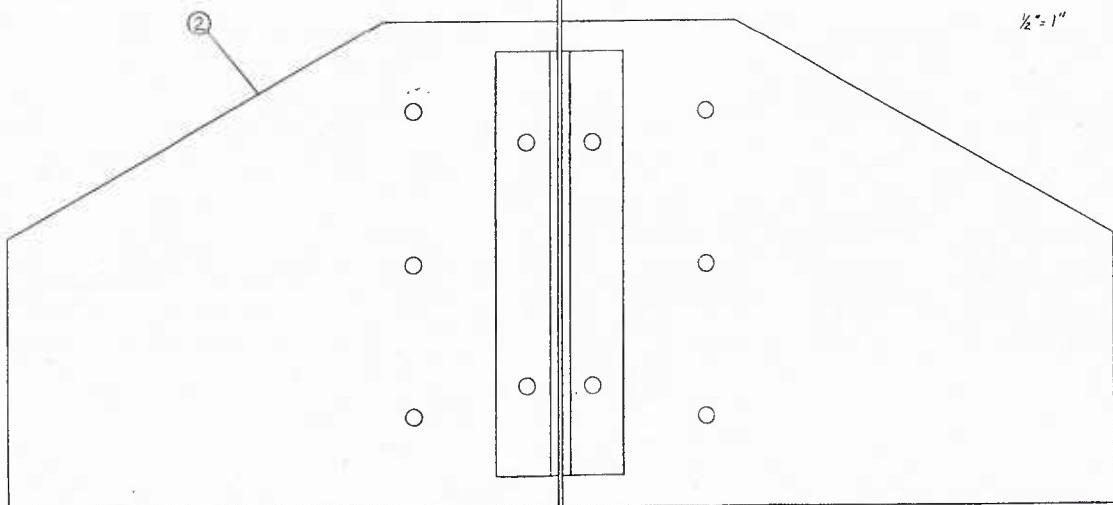
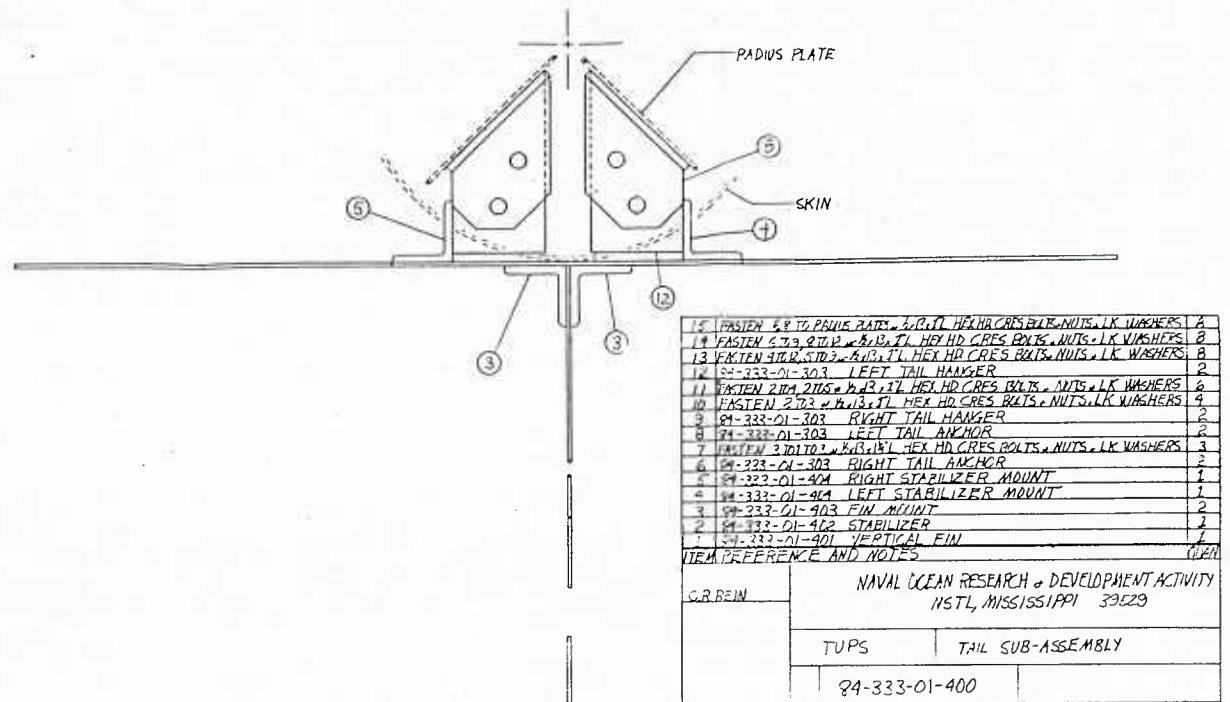
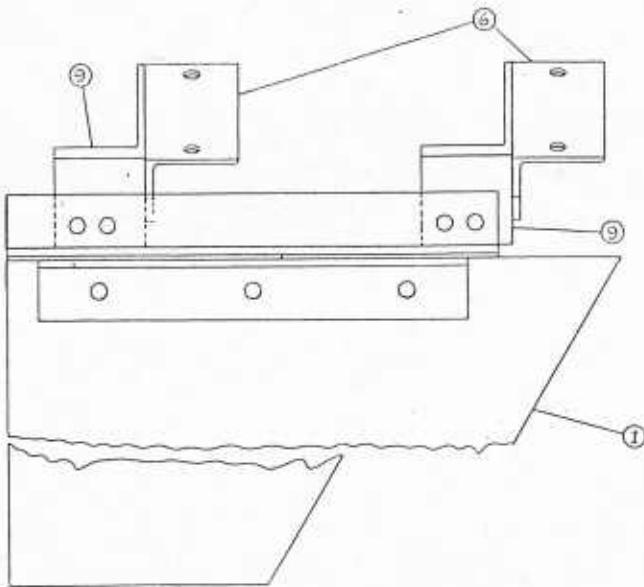


7. RIGHT WING ANCHOR  
8. LEFT TAIL ANCHOR

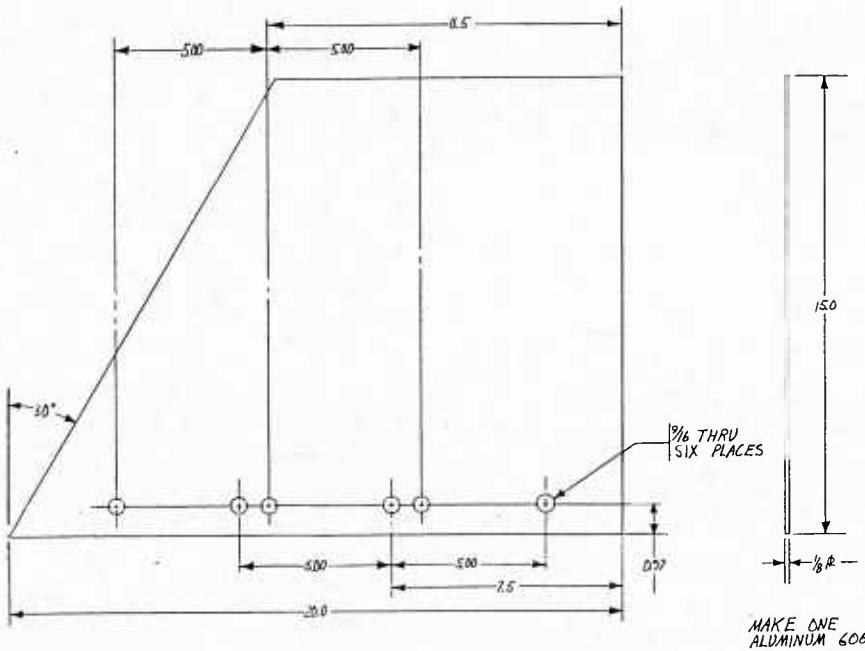


12. MAKE TWO;  $X=6.0$ ,  $Y=0.85$   $3 \frac{1}{2}'' \times \frac{1}{4}''$  ANGLE ALUM 6061-T6  
13. MAKE ONE;  $X=6.4$ ,  $Y=1.25$   $3 \frac{1}{2}'' \times \frac{1}{2}''$  ANGLE ALUM 6061-T6  
14. MAKE ONE;  $X=7.3$ ,  $Y=2.75$   $3 \frac{1}{2}'' \times \frac{1}{2}''$  ANGLE ALUM 6061-T6

DIMENSIONS IN INCHES	
TOLERANCES	
$0.1X$	$\pm 0.050$
$0.1Y$	$\pm 0.015$
FRAC <sub>T</sub>	$\pm \frac{1}{16}$
ANGLE	$\pm 2^\circ$
SCALE	1"-1"
C.R. REIN	COMAR 1984
NAVAL OCEAN RESEARCH AND DEVELOPMENT ACTIVITY NSTL MISSISSIPPI 39529	
WING STABILIZER ANCHORS AND HANGERS 84-333-01-303	



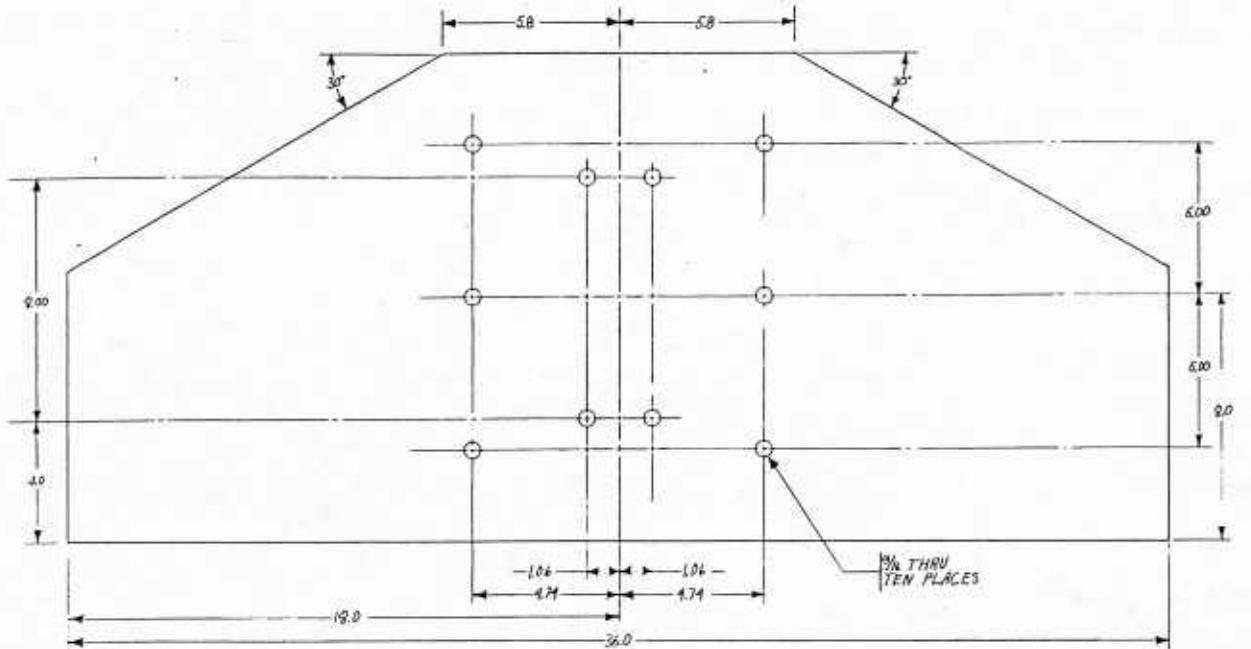
84-333-01-400



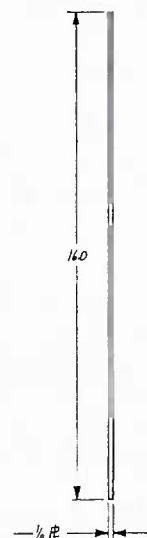
1. VERTICAL FIN

DIMENSIONS IN INCHES  
 TOLERANCES  $D_x \pm 0.050$   
 $D_{xx} \pm 0.015$   
 FRACT.  $\pm \frac{1}{64}$   
 ANGLE  $\pm \frac{1}{2}^\circ$

C.R.REIN	NAVAL OCEAN RESEARCH & DEVELOPMENT ACTIVITY NSTL, MISSISSIPPI 39529	
TUPS	1	VERTICAL FIN
	34-333-01-401	$\frac{1}{2}^\circ \pm 1^\circ$

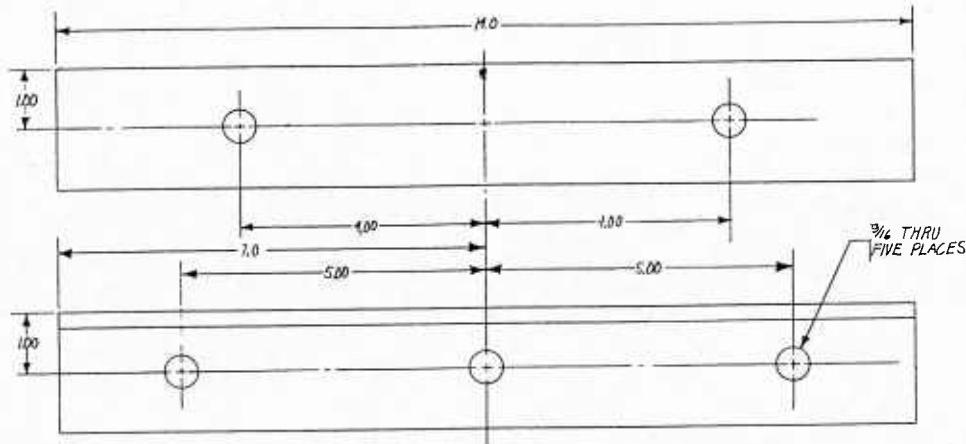


2. STABILIZER



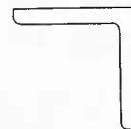
DIMENSIONS IN INCHES  
TOLERANCES OR ± .0050  
OXY ± .015  
FRAC 1/16  
ANGLE ± 1°

G.R.REIN 5 APRIL, 94	NAVAL OCEAN RESEARCH & DEVELOPMENT ACTIVITY NSTL, MISSISSIPPI 39529	
	TUPS	STABILIZER
	84-333-01-902	
	$1/8 = 1^\circ$	



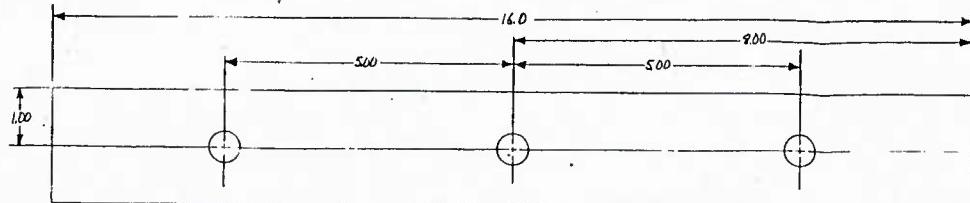
3. FIN MOUNT

MAKE TWO  
2x2x $\frac{1}{4}$  ANGLE  
ALUM 6061-T6

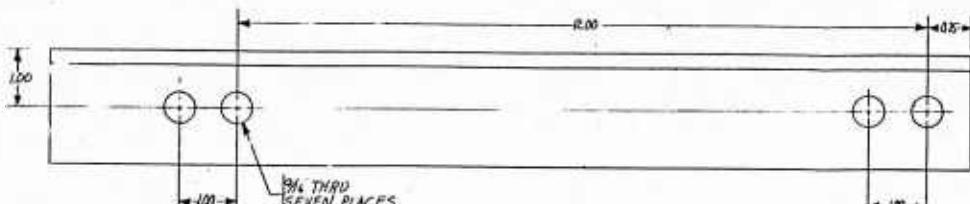
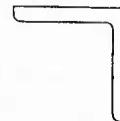


DIMENSIONS IN INCHES  
TOLERANCES  $\Delta x \pm 0.050$   
 $\Delta x \pm 0.015$   
FRCT.  $\pm \frac{1}{64}$

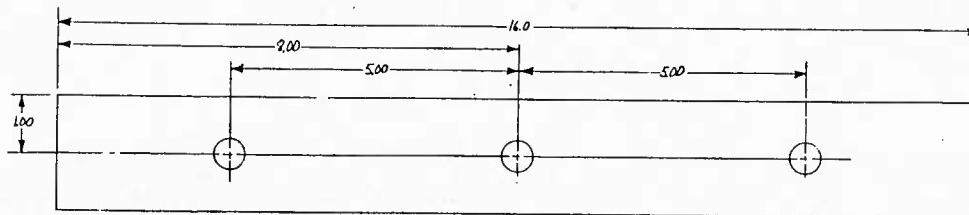
C.R.REIN	NAVAL OCEAN RESEARCH & DEVELOPMENT ACTIVITY NSTL, MISSISSIPPI 39529	
4 APRIL '84		
TUPS	FIN MOUNT	
	84-333-01-103	
$1^{\circ} = 1^{\circ}$		



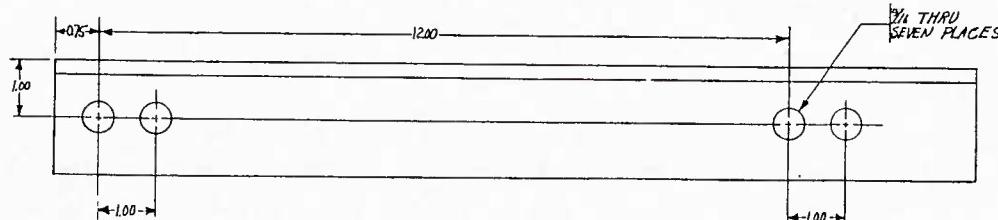
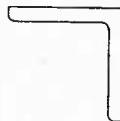
MAKE ONE  
2 $\times$ 2 $\times$  $\frac{1}{4}$  ANGLE  
ALUM. 6061-T6



4 LEFT STABILIZER MOUNT



MAKE ONE  
2 $\times$ 2 $\times$  $\frac{1}{4}$  ANGLE  
ALUM. 6061-T6



5. RIGHT STABILIZER MOUNT

DIMENSIONS IN INCHES  
TOLERANCES DX  $\pm$ 0.000  
AUX 0.015  
FRACT. 1/16

C.R.REIN 4 APRIL '81	NAVAL OCEAN RESEARCH & DEVELOPMENT ACTIVITY NSTL, MISSISSIPPI 39529	
	TUPS	STABILIZER MOUNTS
	84-333-01-104	
	1 $\frac{1}{2}$ "	

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